Push it to the Limit: Low Level Phosphorus Pilot Studies at the Fond du Lac Water Pollution Control Plant

WWOA Annual Conference
October 13, 2016

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Jeremy Cramer and Autumn Fisher, City of Fond du Lac
Outline of Presentation

• Background
• Optimization and Source Reduction
• Tertiary Treatment Technology Pilot Study Results
• Sidestream Phosphorus Harvesting
• Preliminary Cost Evaluation
• Next Steps
9.8 mgd design average flow
Discharge to Lake Winnebago
Fine screens, grit removal, primary clarification, activated sludge with nitrogen removal, chemical P removal (CPR), UV disinfection
WPDES Permit – P Effluent Limits

<table>
<thead>
<tr>
<th>Item</th>
<th>Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current/Interim Limit</td>
<td>1 mg/L</td>
</tr>
<tr>
<td>Future WQBELs</td>
<td></td>
</tr>
<tr>
<td>Six-Month Average</td>
<td>0.04 mg/L</td>
</tr>
<tr>
<td>Monthly Average</td>
<td>0.12 mg/L</td>
</tr>
</tbody>
</table>

*Mass limits are also included*

*WQBEL = Water Quality Based Effluent Limit*
Reissued Permit Sets Timeline for Various Phosphorus Compliance Steps

<table>
<thead>
<tr>
<th>Item</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permit Effective</td>
<td>1/1/13</td>
</tr>
<tr>
<td>Operational Evaluation Report</td>
<td>12/31/13</td>
</tr>
<tr>
<td>Study of Feasible Alternatives:</td>
<td></td>
</tr>
<tr>
<td>Start</td>
<td>12/31/13</td>
</tr>
<tr>
<td>Status Report</td>
<td>12/31/14</td>
</tr>
<tr>
<td>Preliminary Compliance Plan*</td>
<td>12/31/15</td>
</tr>
<tr>
<td>Final Compliance Plan</td>
<td>12/31/16</td>
</tr>
<tr>
<td>Achieve Compliance with 0.04 mg/L**</td>
<td>1/1/2022</td>
</tr>
</tbody>
</table>

*WDNR allowed more of a status report

**if tertiary treatment is selected
## Timeline for Related Initiatives

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<td>12/31/15</td>
</tr>
<tr>
<td>Final Compliance Plan</td>
<td>12/31/16</td>
</tr>
<tr>
<td>Statewide Multidischarger Variance</td>
<td>2016-17?</td>
</tr>
<tr>
<td>Upper Fox/Wolf Total Maximum Daily Load for P</td>
<td>2017?</td>
</tr>
<tr>
<td>Design Treatment Improvements</td>
<td>2017-2018</td>
</tr>
<tr>
<td>Achieve Compliance with 0.04 mg/L</td>
<td>1/1/2022</td>
</tr>
</tbody>
</table>
Study of Feasible Alternatives

Advanced Treatment at WPCP
TMDL*-Based Limit
Site Specific Standard

Watershed Adaptive Management
Water Quality Trading Variances

Feasibility Study

Best Option(s) for Fond du Lac

*TMDL = total maximum daily load
Operational Evaluation and Optimization

- P minimization
- Monitoring
- Full-scale biological phosphorus removal (BPR)
- Optimize chemical addition
  - Ferric Chloride
  - Alum
  - SorbX-100

Left to Right – Ferric Chloride, Alum, SorbX
Influent Load Trend – Last Four Years

Average Phosphorus Load (lbs/day)

- Influent
- Effluent

April-12 to January-16
Full-Scale Chemical P Removal Test with SorbX-100

Nov 8-Dec 17
460 gpd SorbX (72 ppmv)
0.21 mg/L TP, 0.05 mg/L OP

Jan 5-End
210 gpd SorbX (33 ppmv)
0.70 mg/L TP, 0.51 mg/L OP
Full-Scale Chemical P Removal Test Observations

- Reduced struvite
- Cake solids similar
- Polymer use initially lower
- Aquatic toxicity and crop test results favorable
- May be more cost effective for lower limits
Soluble Nonreactive Phosphorus

• Not easily removed with chemical addition
• Can have major impacts on treatment costs
• Influent SNRP in Fond du Lac has varied – often over 0.04 mg/L WQBEL
Soluble Nonreactive P (SNRP) Monitoring
Pilot Studies of Tertiary Treatment Technologies

- Demonstrate ability of technology to achieve anticipated WQBEL
- Evaluate treatment response to stress tests
- Determine appropriate design criteria for full-scale implementation
- Provide familiarity of technologies to City staff
Treatment Technologies Pilot Tested to Date

- COMAG® Ballasted Settling System
- ACTIFLO® Ballasted Settling System
- Ovivo TriSep Membrane System
- Aqua-Aerobic Systems AquaDisk® CMF and UF
- Clearas Water Recovery
- CNP AirPrex® Struvite Harvesting
COMAG® Ballasted Settling System
COMAG® Ballasted Settling System

- September 16, 2013 to October 15, 2013
- Normal operating pilot flow = 50 gpm
- Operated with alum, ferric chloride, and PACl
- Range of coagulant dosages used to generate dose-response curves
COMAG® Ballasted Settling System
COMAG® Ballasted Settling System
• Stress test for high solids – 100 mg/L TSS
• Stress test for high flow – 2X flow
**COMAG® Ballasted Settling System**

<table>
<thead>
<tr>
<th>Coagulant</th>
<th>Pilot Influent TP Average</th>
<th>Pilot Effluent TP Average</th>
<th>TP Percent Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alum</td>
<td>1.0 mg/L</td>
<td>0.039 mg/L</td>
<td>96%</td>
</tr>
<tr>
<td>Ferric Chloride</td>
<td>0.97 mg/L</td>
<td>0.025 mg/L</td>
<td>98%</td>
</tr>
<tr>
<td>PACl</td>
<td>0.91 mg/L</td>
<td>0.040 mg/L</td>
<td>96%</td>
</tr>
</tbody>
</table>

- Required Coagulant Dosages:
  - Alum – 12 mg/L as Al
  - Ferric Chloride – 24 mg/L as Fe
  - PACl – 20 mg/L as Al
- Polymer 0.7-0.8 mg/L dry weight
### COMAG® Ballasted Settling System

<table>
<thead>
<tr>
<th>Coagulant</th>
<th>Influent TSS Average</th>
<th>Effluent TSS Average</th>
<th>TSS Percent Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alum</td>
<td>28.9 mg/L</td>
<td>1.6 mg/L</td>
<td>95%</td>
</tr>
<tr>
<td>Ferric Chloride</td>
<td>19.3 mg/L</td>
<td>1.9 mg/L</td>
<td>90%</td>
</tr>
<tr>
<td>PACI</td>
<td>25.1 mg/L</td>
<td>3.2 mg/L</td>
<td>87%</td>
</tr>
</tbody>
</table>
ACTIFLO® Ballasted Settling System

- June 1st through June 19th, 2015
- 59-242 gpm (8-40 gpm/sf)

Source: Veolia
ACTIFLO® Ballasted Settling System

Source: Veolia
ACTIFLO® Ballasted Settling System

Pilot Study Procedure:

• Coagulant dose optimization
• Polymer dose optimization
• Hydraulic loading rate response
• Extended run to demonstrate performance

• Conducted with Ferric Chloride, Alum, and SorbX-100
ACTIFLO® Ballasted Settling System

Pilot Study Procedure:
- Coagulant dose optimization
- Polymer dose optimization
- Hydraulic loading rate response
- Extended run to demonstrate performance

<table>
<thead>
<tr>
<th>Coagulant</th>
<th>Optimum Dose</th>
<th>Effluent TP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferric Chloride</td>
<td>70-80 mg/L</td>
<td>&gt;0.04 mg/L</td>
</tr>
<tr>
<td>Alum</td>
<td>&gt;220 mg/L</td>
<td></td>
</tr>
<tr>
<td>SorbX-100</td>
<td>80-95 mg/L</td>
<td></td>
</tr>
</tbody>
</table>
ACTIFLO® Ballasted Settling System

Pilot Study Procedure:
- Coagulant dose optimization
- Polymer dose optimization
- Hydraulic loading rate response
- Extended run to demonstrate performance

<table>
<thead>
<tr>
<th>Coagulant</th>
<th>Optimum Dose</th>
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</thead>
<tbody>
<tr>
<td>Ferric Chloride</td>
<td>0.6 to 1.2 mg/L No significant impact</td>
</tr>
<tr>
<td>Alum</td>
<td>-</td>
</tr>
<tr>
<td>SorbX-100</td>
<td>0.6 to 1.2 mg/L No significant impact</td>
</tr>
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ACTIFLO® Ballasted Settling System

Pilot Study Procedure:
• Coagulant dose optimization
• Polymer dose optimization
• Hydraulic loading rate response
• Extended run to demonstrate performance

<table>
<thead>
<tr>
<th>Coagulant</th>
<th>Rise Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferric Chloride</td>
<td>40 gpm/sf</td>
</tr>
<tr>
<td>Alum</td>
<td>-</td>
</tr>
<tr>
<td>SorbX-100</td>
<td>32 gpm/sf</td>
</tr>
</tbody>
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ACTIFLO® Ballasted Settling System

Pilot Study Procedure:
• Coagulant dose optimization
• Polymer dose optimization
• Hydraulic loading rate response
• Extended run to demonstrate performance

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<thead>
<tr>
<th>Coagulant</th>
<th>Influent TP Average</th>
<th>Effluent TP Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferric Chloride</td>
<td>0.67 mg/L</td>
<td>0.04 mg/L</td>
</tr>
<tr>
<td>(32 gpm/sf, 72-100 mg/L)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alum</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>SorbX-100</td>
<td>0.77 mg/L</td>
<td>0.04 mg/L</td>
</tr>
<tr>
<td>(16 gpm/sf, 95 mg/L)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# ACTIFLO® Ballasted Settling System

## Soluble Nonreactive Phosphorus Results

<table>
<thead>
<tr>
<th>Coagulant</th>
<th>Influent SNRP Average</th>
<th>Effluent SNRP Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferric Chloride</td>
<td>0.08 mg/L</td>
<td>0.02 mg/L</td>
</tr>
<tr>
<td>Alum</td>
<td>0.13 mg/L</td>
<td>0.03 mg/L</td>
</tr>
<tr>
<td>SorbX-100</td>
<td>0.07 mg/L</td>
<td>0.03 mg/L</td>
</tr>
</tbody>
</table>
ACTIFLO® Ballasted Settling System
Ovivo TriSep Membrane System

- March 18, 2015 – April 23, 2015
- iSep™ 500-PVDF UF membrane
- 6 gpm pilot unit
- Operated with alum and SorbX-100

Source: TriSep
Ovivo TriSep Membrane System

Source: Ovivo
Ovivo TriSep Membrane
Ovivo TriSep Membrane Pilot Results

- Mar 19-20: 23-104 ppmv SorbX
- Apr 15-19: 69 ppmv Alum
- Mar 25-31: 135 ppmv Alum avg.
- Apr 20-23: 104 ppmv Alum
### Ovivo TriSep Membrane Pilot Results

<table>
<thead>
<tr>
<th>Coagulant</th>
<th>Influent TP Average</th>
<th>Effluent TP Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alum</td>
<td>0.92 mg/L</td>
<td>0.05 mg/L</td>
</tr>
<tr>
<td>SorbX-100</td>
<td>0.23 mg/L</td>
<td>0.07 mg/L</td>
</tr>
</tbody>
</table>

- SorbX found to be incompatible with UF membrane
- Effluent SNRP average ~0.05 mg/L
Aqua-Aerobic Systems AquaDisk®

- September 29 – October 27, 2015
- Cloth media filter and ultrafiltration filter
- CMF – OptiFiber PES-14 polyester microfiber pile
- SorbX used for secondary phosphorus removal for most of pilot – switched to alum toward end of pilot

Source: Aqua-Aerobic Systems Inc.
Aqua-Aerobic Systems Arrangement – AquaDisk Cloth Filter Plus Ultrafiltration Membrane

Polymer plus Ferric Chloride, Alum, or SorbX-100

Source: Aqua-Aerobic Systems Inc.
Aqua-Aerobic Systems Results
### Aqua Aerobic Systems Pilot Test

#### Soluble Nonreactive Phosphorus Results

<table>
<thead>
<tr>
<th>Coagulant</th>
<th>Influent SNRP Average</th>
<th>Cloth Effluent SNRP Average</th>
<th>Membrane Effluent SNRP Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferric Chloride</td>
<td>0.10 mg/L</td>
<td>0.05 mg/L</td>
<td>0.01 mg/L</td>
</tr>
<tr>
<td>Alum</td>
<td>0.10 mg/L</td>
<td>0.02 mg/L</td>
<td>0.01 mg/L</td>
</tr>
<tr>
<td>SorbX-100</td>
<td>0.05 mg/L</td>
<td>0.01 mg/L</td>
<td>-</td>
</tr>
</tbody>
</table>
Clearas Water Recovery

- August 9, 2016 to present
- Advanced Biological Nutrient Recovery (ABNR™) System
- Tertiary treatment system using suspended algae
- Removes phosphorus and nitrogen
- Increases dissolved oxygen
- Produces potentially marketable product
Clearas Water Recovery

Source: Clearas Water Recovery
Clearas Water Recovery
Clearas Water Recovery

Average Influent SNRP: 0.04 mg/L
Average Effluent SNRP: 0.01 mg/L
Clearas Water Recovery
Sidestream Struvite Harvesting

- Harvest from dewatering centrifuge centrate
  - Ostara
  - Multiform Harvest
- Harvest from digested biosolids upstream of centrifuge
  - CNP AirPrex

Struvite - Magnesium Ammonium Phosphate

Source: CNP
CNP AirPrex® Pilot Testing

Goals of P harvesting:

1. Reduce nuisance struvite formation.
2. Increase biosolids cake concentration with less polymer.
3. Recover a marketable struvite fertilizer product.

Source: CNP
CNP AirPrex® Pilot Testing – November 2015
AirPrex® Pilot Test Results

- Reduced soluble orthophosphate by 80 – 90%
- Improved cake solids concentrations at lower polymer dose with pilot centrifuge
  - thermophilic – 5% dryer cake with 16% lower polymer use
  - mesophilic – similar cake with lower polymer; less conclusive

Source: Centrisys
## Preliminary Cost Summary

<table>
<thead>
<tr>
<th>Alternative</th>
<th>20-Year Present Worth Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced TP Removal</td>
<td></td>
</tr>
<tr>
<td>CoMag™</td>
<td>$ 37,900,000</td>
</tr>
<tr>
<td>Blue PRO®</td>
<td>$ 70,300,000</td>
</tr>
<tr>
<td>Ovivo TFS®</td>
<td>$131,000,000</td>
</tr>
<tr>
<td>ACTIFLO</td>
<td>$ 32,800,000</td>
</tr>
<tr>
<td>AquaAerobic DF&lt;sup&gt;1&lt;/sup&gt;</td>
<td>$ 23,100,000</td>
</tr>
<tr>
<td>AquaAerobic DF + UF&lt;sup&gt;2&lt;/sup&gt;</td>
<td>$ 50,100,000</td>
</tr>
</tbody>
</table>

<sup>1</sup>Disk filter
<sup>2</sup>Ultrafiltration

- Clearas Water Recovery full-scale costs currently in development
Next Steps

- Continue to evaluate regulatory options (variance, TMDL).
- Continue to evaluate advanced treatment technologies.
  - Cost for combinations of options (i.e., filtration plus water quality trading).
- Explore potential watershed partnerships and opportunities for BMP implementation.
- Develop Final Compliance Alternatives Plan following TMDL completion.
Acknowledgements – thank you!

- Mulcahy Shaw Water and Molycorp (SorbX-100)
- CNP (AirPrex) and Centrisys
- Peterson & Matz and Kruger/Veolia (ACTIFLO)
- Drydon and AquaAerobics (AquaDisc)
- Energenecs and Ovivo (TriSep)
- Mulcahy Shaw Water and Clearas Water Recovery
Thank you for coming!

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